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(72) Inventor RAYMOND HOLL



**(54) IMPROVEMENTS IN OR RELATING TO APPARATUS FOR VARYING THE INCIDENCE OF TURBOMACHINERY STATOR BLADES**

(71) I, SECRETARY OF STATE FOR DEFENCE, LONDON, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which 5 it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to variable incidence stator blading for axial flow rotary machinery such as the compressors and turbines of gas turbine engines.

It is known, in order to improve both the steady state performance and the handling characteristics of an axial flow rotary machine, that the angular positions of selected rows of stator blades, including entry guides vanes, need to be regulated according to preselected rules. Known methods of controlling the positions of the blades involve the use of hydraulic, or fuelhydraulic, actuated pistons, levers, and rings mounted rotatably external to and surrounding the turbo machine casing. Recent developments involve the use of pneumatic drives, flexible shafts and screw drives. With these types of operating mechanisms some degree of flexibility is inevitable in the operating mechanism. As a result, completely accurate positioning of the blades, other than at positions where the movement of the blades is determined by limiting stops, cannot be precisely controlled.

According to the present invention, an axial flow rotary machine includes a cylindrical casing, at least one row of variable incidence stator blades mounted on the casing and extending radially inwardly within the casing, and means for varying the angles of incidence of the blades including for each row a rotatable ring mounted on a bearing external to and surrounding the casing and connected to the blades, at least one pulley mounted radially outside the ring and connected to the ring by a continuous belt, and means for driving each pulley.

Preferably there are two pulleys mounted diametrically opposite one another.

In one form of the invention the belt is in

the form of a chain running over sprockets on the ring and on the pulley or pulleys.

In another form of the invention the belt is in the form of a wire, preferably a stranded wire, which wraps once completely round the ring and once completely round the or each pulley. The drive means can be hydromatically, pneumatically or electrically driven. In the case of electric drive, pulsed or stepper motors can be effectively integrated directly with digital electronic control means of the type currently being introduced for the control of aircraft gas turbine engines.

The pulley mountings are preferably spring loaded away from the casing to ensure that the belt remains in tension. The bearing may be a ball or roller bearing, with the rotatable ring being the outer race of the bearing. Alternatively the ring may be mounted on a circumferential or segmented ring of anti-friction material.

A plurality of pulleys each to be associated with a separate stator row can be mounted on a single shaft. By varying the diameters of the pulleys differential movement of the separate blade rows can be achieved.

Some embodiments of the invention will now be described, by way of example only, with reference to the diagrammatic drawings accompanying the Provisional Specification, of which

Fig. 1 is an elevation in section of a gas turbine engine of the type used in aircraft.

Fig. 2 is an end view of a rotatable ring mounted on bearings and connected by a continuous stranded wire to a pair of pulleys.

Fig. 3 is a detail sectional view along the lines 33 of Fig. 2.

Fig. 4 is a detail view in the direction of arrow 4 on Fig. 2,

Fig. 5 is a view of a shaft carrying 3 pulleys and driven by two motors,

Fig. 6 is a view in the direction of arrow

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6 of Fig. 5 showing the mounting of a motor, and

Fig. 7 is a detail end view, corresponding to Fig. 2, and showing an alternative means of mounting a rotatable ring.

An aircraft gas turbine engine shown generally at 10 in Fig. 1 has an outer casing 11 and an inner casing 12. Mounted within the casing 12 is a rotor having a compressor 13 connected by a shaft 14 to a turbine disc 15. The compressor 13 has a plurality of rows of rotor blades as indicated at 16. Mounted on the inner casing 12 are a plurality of rows of stator blades as indicated at 17. Certain of the rows of stator blades 17 are rotatable by the action of rotatable rings such as those indicated at 18, as will be described below, to vary their incidence.

Each ring 18 (Fig. 2 and 3) is the outer race of a ball bearing, the inner race 19 of which is rigidly located with respect to the inner casing 12 by spigots such as that shown at 20 in Fig. 3. Between the inner race 19 and the inner casing 12, at each spigot 20 position, is a circumferential Belleville type washer 21 which compensates for any differential expansion between the casing 12 and the inner race 19. A continuous stranded wire 23 passes completely around the ring 18, in which it lies in a channel 22, and also completely round each of two pulleys 24 which lie on a diameter of the engine 10 radially outboard of the ring 18. As will be apparent from Fig. 2 the wire is in contact with the ring 18 and the pulleys 23 over more than  $360^{\circ}$  of their circumferences.

Each pulley 24 (Fig. 5) is mounted on a shaft 25 driven by a motor 26. Fig. 5 shows 3 pulleys 24, each for a different row 17 of stator blades, mounted on a shaft 25 driven by two motors 26. Each motor 26 (Fig. 6) is mounted on a mounting 27 and is spring loaded by a spring 28 away from the inner casing 12.

The stator blades of the rows 17 are rotatably mounted on the inner casing 12 of the engine 10. Each blade, one of which is shown at 29 in Figs. 3 and 4 is mounted within the casing 12 on one end of a rod 30 carried in a bearing 31. The rod 30 projects externally from the casing 12 and at its other end is rigidly secured to a lever 32 an end 34 of which is carried in a recess 33 in the ring 18.

In operation the motors 26 are rotated in synchronism so rotating the shafts 25 and hence the pulleys 24. Rotation of the pulleys 24 serves through the intermediary of the wire 23 to rotate the ring 18. Rotation of the ring 18 moves the ends 34 of the levers 32 so causing rotation of the stator blades 29. The motors 26, which can be hydraulically, pneumatically or electrically driven, are progressively activated in response to various engine parameters accord-

ing to methods well known in the art. To prevent overrunning stops (not shown) may be fitted either to the motors 26 or to prevent excessive rotation of the ring 18.

It will be apparent that in the embodiment described above any loads applied to the casing 12 will be symmetrically distributed. As the loads required to rotate the stator blades 29 are comparatively small the amount of tension in the wire 23 to prevent friction will not be excessive. In any event, when stops are fitted to prevent excessive rotation of the ring 18, any slipping of the wire 23 will be automatically compensated during one cycle of stator blade 29 rotation. It will also be apparent that as an alternative to the wire 23 a chain running in sprockets in the ring 18 and on the pulleys 24 will operate as does the wire 23. When using a chain it will not be necessary for the chain to completely encircle the ring 18 and pulleys 24. Also using a chain, as the chain need only be sufficiently tensioned to avoid slipping a sprocket, so minimising loading on the inner casing 12, only one pulley 24 may be required.

Many variations of the above described embodiment are possible within the scope of the invention. For example, the shaft 25 may be supported adjacent the pulleys 24 in spring mounted bearings, the motors 26 being rigidly mounted on the casing 12 in such a way as to allow some end float of the shaft 25. It will frequently be possible to use only one motor 26 with the undriven end of the shaft 25 being supported by a bearing. This particularly applies when a shaft 25 has only one pulley 24 mounted thereon. As an alternative to being the outer race of a ball bearing the ring 18 can be the outer race of a roller bearing, or may, as illustrated in Fig. 7 be mounted on a plurality of segments such as that shown at 35 mounted circumferentially around the casing 12, each segment 35 having a surface 36 of anti-friction material.

Whilst the above description with reference to Figures 1 to 7 refers to rotation of compressor stator blades, it will be appreciated that the same drive means can be used to rotate turbine stator blades.

#### WHAT I CLAIM IS:—

1. An axial flow rotary machine including a cylindrical casing, at least one row of variable incidence stator blades mounted on the casing and extending radially inwardly within the casing, and means for varying the angles of incidence of the blades including for each row a rotatable ring mounted on a bearing external to and surrounding the casing and connected to the blades, at least one pulley mounted radially outside the ring and connected to the ring by a contin-

uous belt, and means for driving each pulley.

2. An axial flow rotary machine as claimed in claim 1 wherein there are for each rotatable ring two pulleys mounted diametrically opposite one another.

5 3. An axial flow rotary machine as claimed in claim 1 or in claim 2 wherein the belt is in the form of a chain which runs over sprockets on the ring and on the pulley or pulleys.

10 4. An axial flow rotary machine as claimed in claim 1 or in claim 2 wherein the belt is in the form of a wire which wraps once completely round the ring and round the or each pulley.

15 5. An axial flow rotary machine as claimed in any one of claims 1 to 4 having several rows of variable incidence stator blades wherein a plurality of pulleys are secured to a common rotatable shaft.

20 6. An axial flow rotary machine as claimed in claim 5 wherein the pulleys mounted on a common shaft have different diameters.

25 7. An axial flow rotary machine as claimed in any one of claims 1 to 6 wherein the or each pulley mounting is spring loaded away from the casing.

30 8. An axial flow rotary machine as claimed in any one of claims 1 to 7 wherein the or each pulley is associated with hydrodynamic driving means.

9. An axial flow rotary machine as claimed in any one of claims 1 to 7 wherein the or each pulley is associated with pneumatic driving means.

10. An axial flow rotary machine as claimed in any one of claims 1 to 7 wherein the or each pulley is associated with electrical driving means.

40 11. An axial flow rotary machine as claimed in claim 10 wherein the electrical driving means include a pulsed motor.

12. An axial flow rotary machine as claimed in claim 10 wherein the electrical driving means include a stepper motor.

45 13. An axial flow rotary machine as claimed in claim 11 or in claim 12 wherein the electrical driving means are integrated with digital electronic control means.

14. An axial flow rotary machine as claimed in any one of claims 1 to 13 wherein the bearing is a ball or roller bearing.

50 15. An axial flow rotary machine as claimed in any one of claims 1 to 13 wherein the bearing is a circumferential ring of anti-friction material.

16. An axial flow rotary machine as claimed in any one of claims 1 to 13 wherein the bearing is a segmented ring of anti-friction material.

55 17. An axial flow rotary machine substantially as described with reference to the drawings accompanying the Provisional Specification.

F. R. ROBINSON,  
Chartered Patent Agent,  
Agent for the Applicant.

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Sheet 1

FIG. 1.

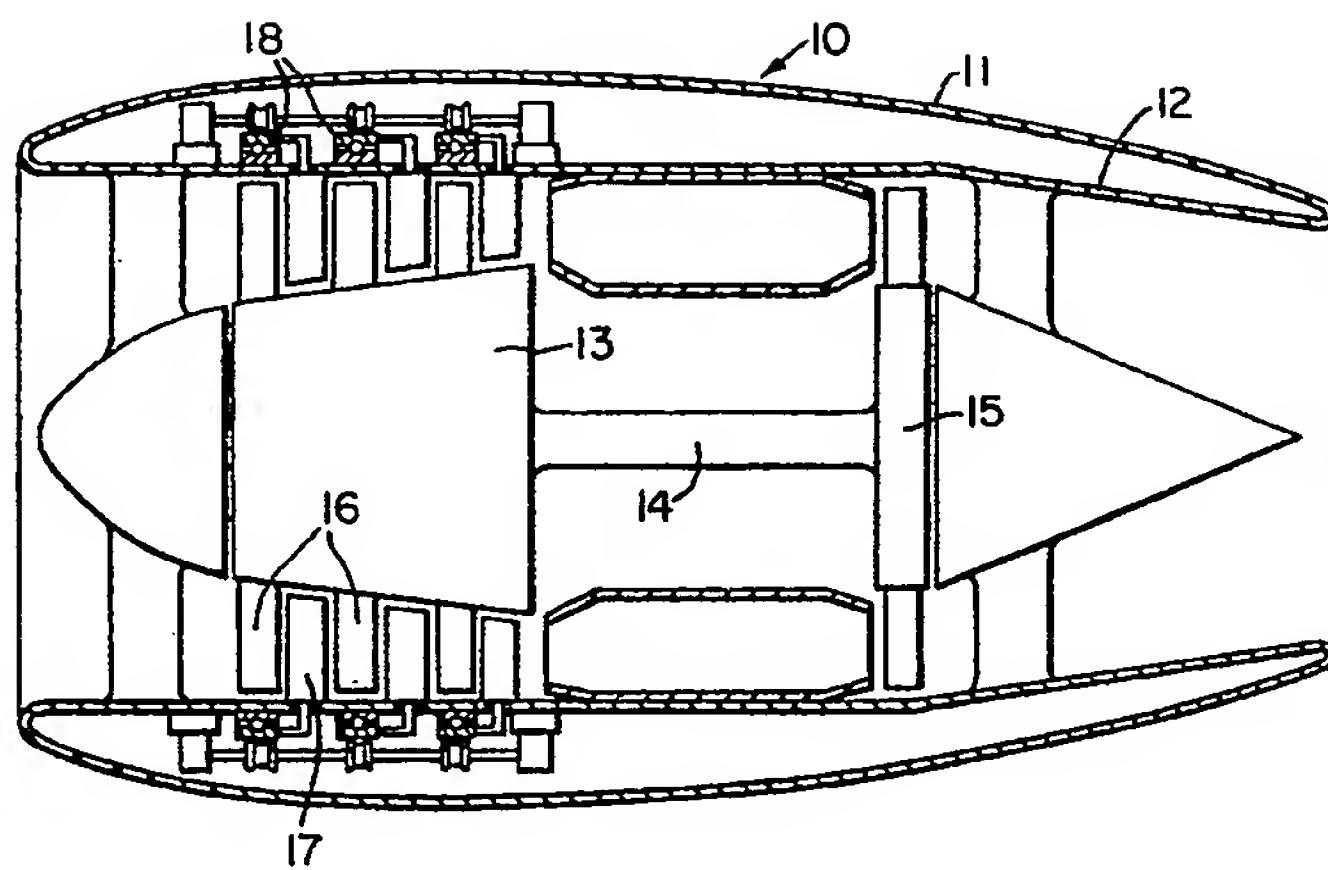
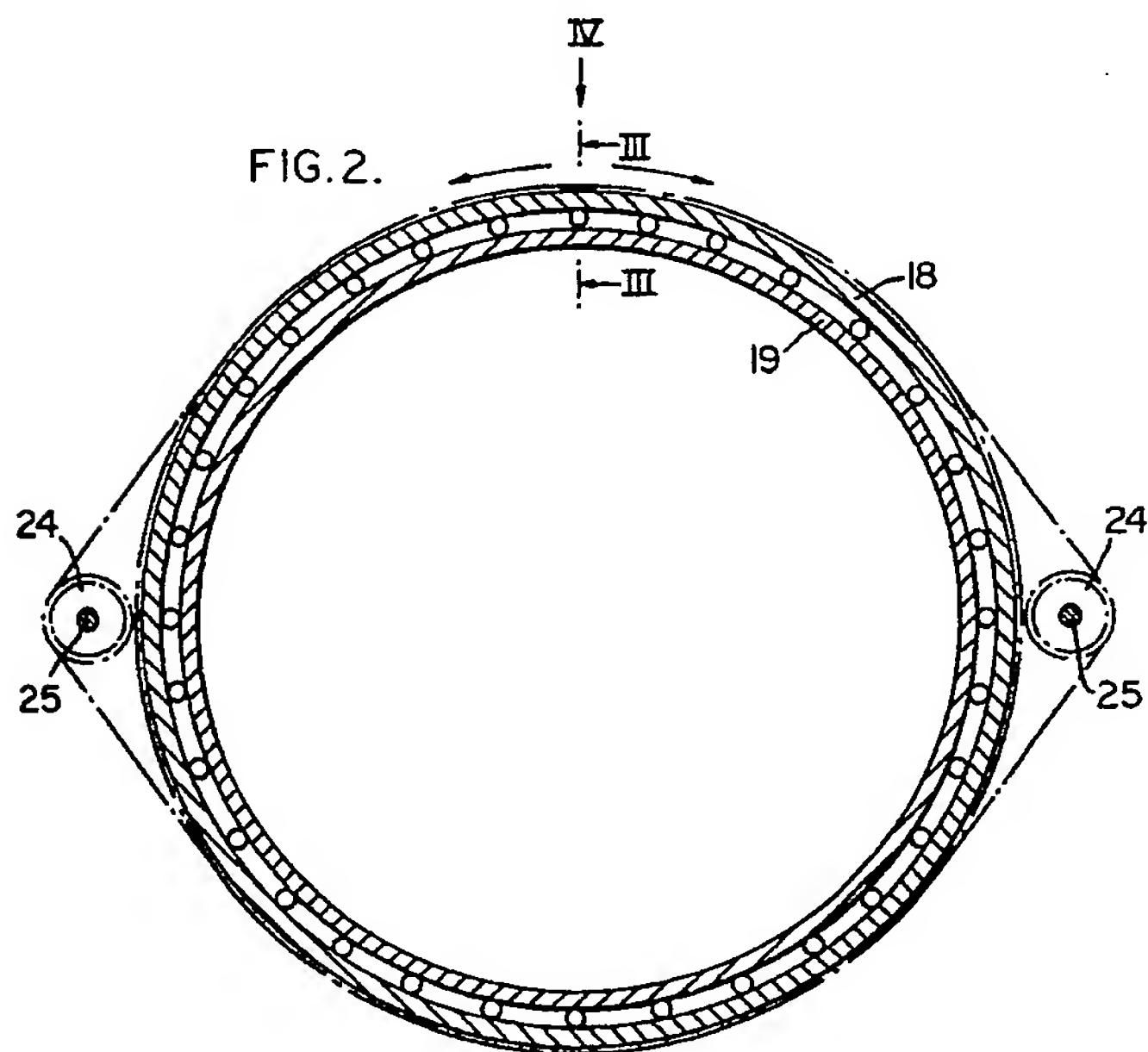


FIG. 2.



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Sheet 2

